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USING GIS FOR GEOLOGIC MAPPING AND COAL RESERVES ESTIMATION

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INTRODUCTION

This manual has been prepared to aid field personnel in using the Bureau of Land Management's (BLM) Geographic Information System (GIS) to store, retrieve, analyze and model spatial data for use in coal tract analysis. GIS can be used to generate contour maps, calculate coal tonnage and overlay several maps to create a composite map. GIS can also be used to edit data files and generate reports.

The two GIS software packages discussed in this manual include the Map Overlay Statistical System (**MOSS**) and the Map Analysis and Processing System (**MAPS**).

If you have any GIS-related questions, contact the **HOTLINE** at FTS 776-0990 or commercial (303) 236-0990.

SECTION ONE: METHODS TO CREATE A DRILLHOLE-LOCATION MAP

GIS can process non-map data and transform the data into a positionally correct, coordinate-referenced map. To create the drillhole-location map, there are four general methods in which this can be done:

Method 1: DIGITIZING

A drillhole-location map can be generated by digitizing points from a basemap using an electronic graphics tablet and a manually-operated cursor that encodes the coordinates for each point using the Automated Digitizing System (**ADS**). The digital coordinates can then be automatically reformated into a **MOSS** map that is compatible with multiple attributes. (Scan digitizing may be economical in the near future.)

Method 2: COALSYS

If the data are in **COALSYS**, use that software's programs to generate an import file for **MOSS**. The **COALSYS** manual will explain how to do this. This method generates an import file, not a map. The import file is then used with the **IMPORT** command to generate a map.

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Method 3: GGWL

A program called Generate Graphic Well Locations (GGWL) can generate the UTM coordinate values from location footages (feet from section lines).

Method 4: XYSUBJECT

If the data are from some other data base, download an ASCII (alphanumeric text) file that contains the drill-hole identifier and coordinates for each point. Then use the **MOSS UTILITY-XYSUBJECT** command (menu option #16) to reformat the coordinate-data file into an import file that can be used by the **IMPORT** command to generate a map.

Method 4 (**XYSUBJECT**) is addressed in the following sections of this manual.

SECTION TWO: USING XYSUBJECT METHOD TO CREATE THE IMPORT FILE

This is a short example of a coordinate file:

```
DH-1   44.6789 107.7654
DH-2   43.9999 107.5555
```

XYSUBJECT asks if the coordinates are in decimal degrees, meters or feet and displays a counter line above the first line in the coordinate file as shown below:

```
12345678901234567890123456789912345678901234567890
DH-1   44.6789 107.7654
```

The program then asks the user enter the "format statement". The provided format is unique to the coordinate file. In this case, the format for the above example is:

```
(T16,F8.4,T8,F7.4,T1,A4)
```

This instructs the program to:

- tab over to column 16 for the X-coordinate, which is a real number with a field length of 8 spaces and 4 spaces to the right of the decimal point
- tab over to column 8 for the Y-coordinate, which is a real number with a field length of 7 spaces and 4 spaces to the right of the decimal point
- tab over to column 1 to find the subject which is character in type and has a field length of 4 spaces

The import files should be named with the suffix .IMP so that they can be easily identified as import files. **XYSUBJECT** will automatically name the output file XY.IMP. This should be renamed as the next run of **XYSUBJECT** will overwrite this file.

FACTS TO REMEMBER:

The subject and coordinates in the coordinate file may be in any columns as long as there is one row per drill hole.

The coordinates may be in latitude/longitude (decimal degrees), feet or meters.

Latitude/longitude must be in decimal degrees. Latitude/longitude coordinate data can be converted to decimal degrees using the formula:

decimal degrees = degrees + (minutes * 60) + (seconds * 3600)

FIGURE 1 shows an example of an output file from the **XYSUBJECT** command. The format of the output file is:

Line 1:	I5	Item number; this is a negative integer if coordinates are in latitude and longitude; right justified
	10x	Ten blank spaces
	30A	Subject, e.g., the drill-hole number
	5x	Five blank spaces
	I5	Number of coordinate pairs; integer; right justified

Line 2 for coordinates other than latitude/longitude:

F11.2	X-coordinate
F11.2	Y-coordinate

Line 2 for latitude/longitude coordinates:

F10.5	Longitude in decimal degrees
F10.5	Latitude in decimal degrees

SECTION THREE: CREATE THE DRILLHOLE-LOCATION MAP

STEP 1. IMPORT THE THE COORDINATE (.IMP) FILE

FACTS TO REMEMBER:

Input file must be in MOSS import format.

Must enter the correct number of map subjects that are in the .IMP file to be imported. To find this number,

FIGURE 1. Example of an import file that include identification labels for the points and their X-Y coordinates.

```
   1          SJ45                                              1
 221484.00 4010740.00
   2          A-11                                              1
 210176.19 4015977.00
   3          B94                                               1
 210055.59 4014987.00
   4          A-12                                              1
 211221.59 4016059.00
   5          A-13                                              1
 211809.59 4015943.00
   6          A-14                                              1
212393.38 4016064.00
   7          B69                                               1
 211936.88 4014941.00
   8          B50                                               1
 213124.88 4014932.00
   9          B39                                               1
 213855.78 4015471.00
  10          B23                                               1
 214769.59 4016115.00
  11          B25                                               1
 214716.50 4015469.00
  12          TL-7-1                                            1
 215810.69 4015678.00
  13          TL-7-2                                            1
 216508.50 4015585.00
  14          A-19                                              1
 215757.69 4014855.00
  15          A-20                                              1
 216330.78 4014789.00
  16          A-21                                              1
 217359.38 4014940.00
  17          TL-8-1                                            1
 217506.69 4015734.00
  18          TL-8-2                                            1
 218451.50 4015730.00
  19          A-23                                              1
 219150.09 4015748.00
  20          A-22                                              1
 218454.38 4014711.00
```

either **SLIST** the .IMP file at the PRIMOS level or use the EMACS editor to find the last sequence number.

Must enter a scale factor: latitude/longitude files will use 100000 as a scale factor; for other projections use 100.

Must enter the correct data type (point).

Other information asked for by the command is for the map header information and has no effect on the calculations.

FIGURE 2 is an example of the **IMPORT** command in which the import file name is COAL.IMP and the coordinates are in latitude/longitude.

STEP 2. REPROJECT THE LATITUDE/LONGITUDE MAP

If the original coordinate file was in latitude/longitude, use the **PROJECTION** command to reproject the imported map to another projection, such as UTM or State Plane. FIGURE 3 gives an example of the **PROJECTION** command to change the latitude/longitude projection into UTM.

SECTION FOUR: LINK MULTIPLE ATTRIBUTES TO THE DRILLHOLE-LOCATION MAP

STEP 1. CREATE THE DATA FILE

The data file contains the multiple attributes (e.g., elevation) for each drillhole-location on the map. Naming convention gives the suffix .DAT or .ATT for the file. The following are examples of multiple attribute filenames:

COAL.DAT MILS.DAT UINTAH.ATT PI.ATT

The multiple attribute file may be a considered a two-dimensional table composed of rows and columns. Rows in the table represent individual drillhole-locations or items:

Row 1 will correspond to Item 1 in the map;
Row 2 will correspond to Item 2 in the map; etc.

Columns are grouped into attribute fields and each attribute field must contain a single type of data. For example, Columns 1 through 4 may be the drill-hole identifier, columns 8 through 11 the coal thickness, and so forth. The length of an attribute field must be the same within each row.

Here is an example of a multiple attribute file for 3 drill holes:

```
DH-1  2  11.5  136.5    1.0  149.0  5958
DH-2  6  22.0  101.0   73.6  196.6  5979
DH-3  3  36.8  120.0   80.2  220.5  5997
```

FIGURE 2. LISTING OF THE IMPORT COMMAND.

```
ENTER COMMAND ?  IMPORT COALPTS.IMP
What do you wish to call the new map ?


  _________
  : COALPTS
 Enter NAME of map to use as a template for the new map header or enter
CARRIAGE RETURN to start map header from scratch :

ENTER SOURCE OF MAP  [                    ]
 : IMPORT
ENTER  CREATION DATE  [          ]
 : 1989
ENTER  STUDYAREA NAME [          ]
 : OZ
ENTER  DESCRIPTION
[                                                    ]
__________________________________________________________
 : COAL POINTS FOR TRAINING
ENTER  MAP VINTAGE  [    ]
 : 1989
ENTER NUMBER OF SUBJECTS [    1]
 : 45
ENTER COORDINATE SCALE FACTOR [    100.0000]
 : 100

    MAP PROJECTION

# 0 PROJECTION IS GEOGRAPHIC(LON/LAT)
 COORDINATE UNITS ARE: DEGREES
DO YOU WISH TO CHANGE THE PROJECTION DESCRIPTION [N]:
 Y
PROJECTION(0-20) ?
 1
ELLIPSOID(0-19) ?
 0
LONGITUDE OF ANY POINT WITHIN THE UTM ZONE ?
 -108
LATITUDE OF ANY POINT WITHIN UTM ZONE   13 ?
 36
IS THIS HEADER INFORMATION CORRECT [Y]
 :Y
ENTER DATATYPE
   1 = POINT                    11 = (X,Y,Z) POINT
   2 = LINE                     12 = (X,Y,Z) LINE
   3 = POLYGON                  13 = (X,Y,Z) POLYGON
   5 = SAMPLE ELEVATION POINT
 : 1
 EXECUTING...PLEASE WAIT
```

```
IMPORT COMPLETE FOR THE NEW MAP: COALPTS
45 ITEMS AND    45 SUBJECTS IN THE NEW MAP
THE INPUT FILE IS COALPTS.IMP
DO YOU WISH TO DELETE THE INPUT FILE  [N]
 : N
 **** STOP
```

FIGURE 3. Listing of the **PROJECTION** command.

```
ENTER COMMAND ?  PROJECTION 1
What do you wish to call the new map ?   PROJ.MAP
WHAT IS THE PROJECTION OF THE INPUT MAP ?

      MAP PROJECTION
  # 0 PROJECTION IS GEOGRAPHIC(LON/LAT) COORDINATE UNITS ARE: DEGREES

                     MAP PROJECTION MENU
0 GEOGRAPHIC(LAT/LON)
1 UNIVERSAL TRANSVERSE MERCATOR  11 LAMBERT AZIMUTHAL EQUAL AREA
2 STATE PLANE                    12 AZIMUTHAL EQUIDISTANT
3 ALBERS CONICAL EQUAL AREA      13 GNOMONIC
4 LAMBERT CONFORMAL CONIC        14 ORTHOGRAPHIC
5 MERCATOR                       15 VERTICAL NEAR SIDE PERSPECTIVE
6 POLAR STEREOGRAPHIC            16 SINUSOIDAL
7 POLYCONIC                      17 EQUIRECTANGULAR (PLATE CARREE)
8 EQUIDISTANT CONIC A & B        18 MILLER CYLINDRICAL
9 TRANSVERSE MERCATOR            19 VAN DER GRINTEN I
10 STEREOGRAPHIC                  20 OBLIQUE MERCATOR (HOTINE)

PROJECTION(0-20) ?
0

    MAP PROJECTION
# 0 PROJECTION IS GEOGRAPHIC(LON/LAT)
 COORDINATE UNITS ARE: DEGREES
Press CR to continue?

WHAT IS THE PROJECTION FOR THE OUTPUT MAP ?

                     MAP PROJECTION MENU
0 GEOGRAPHIC(LAT/LON)
1 UNIVERSAL TRANSVERSE MERCATOR  11 LAMBERT AZIMUTHAL EQUAL AREA
2 STATE PLANE                    12 AZIMUTHAL EQUIDISTANT
3 ALBERS CONICAL EQUAL AREA      13 GNOMONIC
4 LAMBERT CONFORMAL CONIC        14 ORTHOGRAPHIC
5 MERCATOR                       15 VERTICAL NEAR SIDE PERSPECTIVE
6 POLAR STEREOGRAPHIC            16 SINUSOIDAL
7 POLYCONIC                      17 EQUIRECTANGULAR (PLATE CARREE)
8 EQUIDISTANT CONIC A & B        18 MILLER CYLINDRICAL
9 TRANSVERSE MERCATOR            19 VAN DER GRINTEN I
10 STEREOGRAPHIC                  20 OBLIQUE MERCATOR (HOTINE)

PROJECTION(0-20) ?  1

           ELLIPSOID MENU
 0 CLARKE 1866 (default)    10 MODIFIED EVEREST
 1 CLARKE 1880              11 MODIFIED AIRY
 2 BESSEL                   12 WALBECK
 3 NEW INTERNATIONAL 1967   13 SOUTHEAST ASIA
 4 INTERNATIONAL 1909       14 AUSTRAILIAN NATIONAL
 5 WGS 72                   15 KRASOVSKY
 6 EVEREST                  16 HOUGH
 7 WGS 66                   17 MERCURY 1960
 8 GRS 1980                 18 MODIFIED MERCURY 1968
 9 AIRY                     19 SPHERE OF RADIUS 6370997 M

 ELLIPSOID(0-19) ?   0
 LONGITUDE OF ANY POINT WITHIN THE UTM ZONE ?  -108
 LATITUDE OF ANY POINT WITHIN UTM ZONE    13 ?    36

     MAP PROJECTION

 # 1 UNIVERSAL TRANSVERSE MERCATOR
  COORDINATE UNITS ARE: METERS
 VALUES OF ENTERED PARAMETERS
 ----------------------------
 ELLIPSOID SELECTED IS TYPE                                  0
 SEMI-MAJOR AXIS OF ELLIPSOID                  6378206.4000000
 ECCENTRICITY SQUARED OF ELLIPSOID                   0.0067687
 ZONE                                                       13
 LONGITUDE                                        -108.0000000
 LATITUDE                                           36.0000000

 Output projection satisfactory (Y/N) [CR=Y] :  YES
 ENTER SOURCE OF MAP:     IMPORT
 ENTER  CREATION DATE:      1989
 ENTER  DESCRIPTION:      COAL MAP IN UTM PROJECTION
 ENTER COORDINATE SCALE FACTOR:   100

IS THIS HEADER INFORMATION CORRECT:  YES

 PROJECTING...PLEASE WAIT
 **** STOP
```

or it could look like this without the spaces between attribute fields:

```
DH-1211.5136.5 1.0149.05958
DH-2622.0101.073.6196.65979
DH-3336.8120.080.2220.55997
```

FACTS TO REMEMBER:

There may be up to 200 attributes per drill hole.

Each attribute field must contain a single type of data.

Attribute fields for each drill hole must be of the same length and type.

An attribute field must not be greater than 70 characters in length.

The order of the rows must exactly match the item number order of the drillhole-location map. (If the data file is not in the proper order, use the **UTILITY-ATTRIBUTE-RESEQUENCE** command to reorder the multiple attribute file.)

There are three DATA TYPES:

CHARACTER - all the printable ASCII characters including numerics, symbols and spaces. Characters are left justified within an attribute field.
EXAMPLE: DH-1

REAL - positive and negative real numbers as large as 1.8 x 10^{63} and as small as 1.0 x 10^{-63}. The format for real numbers is deterimined by the format statement. For example, F7.4 means there are a total of 7 spaces with 4 numbers to the right of the decimal.
EXAMPLE: 44.9876

INTEGER - positive and negative integer numbers as large as 32,000. No decimal points allowed. An integer larger than 32,000 must be encoded as character data or have a scaling factor applied to the values. An integer is right justified within an attribute field.
EXAMPLE: 6678

STEP 2. CREATE THE DEFINITION FILE

The user must create a definition file before adding the attributes to the drillhole-location map. The definition file stores information about each attribute field within a data file, such as:

ATTRIBUTE (KEY) NAME [up to 10 characters with no spaces]
DESCRIPTION of the attribute [up to 60 characters]
DATA TYPE [integer, real or character]
FIELD WIDTH [number of spaces for the attribute; limitations according to data type]

* A DEFINITION FILE IS UNIQUE TO THE DATA FILE IT IS DEFINING. *

Naming convention gives the suffix .DEF to a definition file. Here are some examples of definition filenames:

COAL.DEF PI.DEF

This file can be created interactively using the **UTILITY-ATTDESCRIBE** command. However, before using **ATTDESCRIBE**, determine the format of the attribute file. For example, the first line in a file COAL.DAT might look like this:

```
DH-1 2 11.5 136.5 1.0 149.0 5958
```

Drill-hole identification (DH-1) is in columns 1-4 and is character type.
Number of coal beds (2) is in spaces 5-6 and is an integer.
Total coal thickness (11.5) is in spaces 7-11 and is a real number with one place to the right of the decimal.
Overburden (136.5) is in spaces 12-17 and is a real number with one place to the right of the decimal.
Total interburden (1.0) is a real number, spaces 18-21.
Total depth (149.0) is a real number, spaces 22-27.
Surface elevation (5958) is an integer, spaces 28-32.

Note that every space has been accounted for, as **ATTDESCRIBE** assumes there are no spaces between attribute fields. If the file has spaces between fields, either edit these spaces out of the attribute file or create the definition file and then edit the definition file.

Refer to FIGURE 4 for an example of the **ATTDESCRIBE** command.

STEP 3. ADD THE ATTRIBUTES

FIGURE 5 is an example of the **UTILITY - ADD ATTRIBUTE** command, which adds the attributes to the map by using the definition file (.DEF) and the data file (.DAT or .ATT). This command creates a binary file that has a mapname.AT filename. For example, a map named COAL.UTM would have a binary attribute file named COAL.UTM.AT.

FIGURE 4. Listing of the **UTILITY-ATTDESCRIBE** command.

```
ENTER COMMAND ?  UTIL
ENTER MOSS UTILITY OPTION
1  =  TERMINATE UTILITY SESSION   [DEFAULT]
2  =  DATABTEST    (MOSS MAP NAMES SUPPORT)
3  =  ATTRIBUTE    (MOSS MULTIPLE ATTRIBUTE SUPPORT)
4  =  ATTDES       (BUILD MULTIPLE ATTRIBUTE DEFINITION FILE)
5  =  SUB2AT       (SUBJECT TO MULTIPLE ATTRIBUTE INPUT)
6  =  APROJ        (MOSS MAP NAMES PROJECTION ASSIGNMENT)
7  =  BROWZ        (MOSS MAP NAMES HEADER LISTING)
8  =  PLOT.LEGEND (BUILD PLOTTER LEGEND FILE)
9  =  MAKE.LOGO    (BUILD PLOTTER LOGO FILE)
10  =  SUBEDIT      (MAP SUBJECT EDIT PROGRAM)
11  =  SET.LEVEL    (BUILD POLYCELL TRANSLATION FILE)
12  =  TRANSFORM    (TRANSFORM COORDINATES TO A PROJECTION)
13  =  QUAD         (MAKE A QUAD MAP IN IMPORT/EXPORT FORMAT)
14  =  DLG3         (USGS DLG ASCII TO MOSS)
15  =  MAPIDX       (MAKE INDEX MAP OF PROJECT IN IMPORT/EXPORT FORMAT)
16  =  XYSUBJECT    (REFORMAT POINT DATA TO MOSS)
: 4
      *** ATTRIBUTE DESCRIPTION PROGRAM ***

What do you wish to call the Definition File?
    COAL.DEF
Provide a ten character description for "KEY"    1 [CR=Exit]
    DRILLHOLE
Provide a 60 character description of this "KEY"
    DRILL HOLE NUMBER
The field type of this "KEY" is
1 - Integer  2 - Floating point  3 - Character
Select:  3
What is the field length of this "KEY"?   6

Attribute:          1    Key:       DRILLHOLE
Description:  DRILL HOLE NUMBER
Type:     CHARACTER    Length:        6

Edit options:  [0] - Proceed to next attribute (#   2)
                1  - Edit attribute KEY
                2  - Edit attribute DESCRIPTION
                3  - Edit field TYPE and LENGTH
                4  - QUIT
                5  - ABORT
Select: 0

Provide a ten character description for "KEY"    2 [CR=Exit]
   THICKNESS
Provide a 60 character description of this "KEY"
   THICKNESS OF THE COAL BED
The field type of this "KEY" is
```

```
1 - Integer  2 - Floating point  3 - Character
Select:  2
What is the field length of this "KEY"?  4
How many digits to the right of the decimal point? 1

Attribute:        2    Key:      THICKNESS
Description:  THICKNESS OF THE COAL BED
Type:          REAL    Length:       4. 1

Edit options:  [0] - Proceed to next attribute (#   3)
                1  - Edit attribute KEY
                2  - Edit attribute DESCRIPTION
                3  - Edit field TYPE and LENGTH
                4  - QUIT
                5  - ABORT
Select:  0

Provide a ten character description for "KEY"   3 [CR=Exit]
   STRUC.TOP
Provide a 60 character description of this "KEY"
   ELEVATION OF TOP OF COAL BED
The field type of this "KEY" is
1 - Integer  2 - Floating point  3 - Character
Select:  1
What is the field length of this "KEY"?  5

Attribute:        3    Key:      STRUC.TOP
Description:  ELEVATION OF TOP OF COAL BED
Type:       INTEGER    Length:       5

Edit options:  [0] - Proceed to next attribute (#   4)
                1  - Edit attribute KEY
                2  - Edit attribute DESCRIPTION
                3  - Edit field TYPE and LENGTH
                4  - QUIT
                5  - ABORT
Select: 4

**** STOP
```

FIGURE 5. Sample run of the **MOSS** command **UTILITY** to add attributes to the drillhole-location map.

```
 ENTER COMMAND ?  UTILITY
 ENTER MOSS UTILITY OPTION
 1   =  TERMINATE UTILITY SESSION    [DEFAULT]
 2   =  DATABTEST    (MOSS MAP NAMES SUPPORT)
 3   =  ATTRIBUTE    (MOSS MULTIPLE ATTRIBUTE SUPPORT)
 4   =  ATTDES       (BUILD MULTIPLE ATTRIBUTE DEFINITION FILE)
 5   =  SUB2AT       (SUBJECT TO MULTIPLE ATTRIBUTE INPUT)
 6   =  APROJ        (MOSS MAP NAMES PROJECTION ASSIGNMENT)
 7   =  BROWZ        (MOSS MAP NAMES HEADER LISTING)
 8   =  PLOT.LEGEND  (BUILD PLOTTER LEGEND FILE)
 9   =  MAKE.LOGO    (BUILD PLOTTER LOGO FILE)
10   =  SUBEDIT      (MAP SUBJECT EDIT PROGRAM)
11   =  SET.LEVEL    (BUILD POLYCELL TRANSLATION FILE)
12   =  TRANSFORM    (TRANSFORM COORDINATES TO A PROJECTION)
13   =  QUAD         (MAKE A QUAD MAP IN IMPORT/EXPORT FORMAT)
14   =  DLG3         (USGS DLG ASCII TO MOSS)
15   =  MAPIDX       (MAKE INDEX MAP OF PROJECT IN IMPORT/EXPORT FORMAT)
16   =  XYSUBJECT    (REFORMAT POINT DATA TO MOSS)
: 3

PLEASE ENTER MAP NAME:   COAL.PTS

THE NUMBER OF ATTRIBUTES IS     0
THE NUMBER OF ITEMS IS         45

PLEASE ENTER DESIRED OPTION
  1  =  EXIT   [DEFAULT]
  2  =  ADD A NEW ATTRIBUTE
  3  =  UPDATE AN EXISTING ATTRIBUTE
  4  =  CHANGE/DELETE KEY OR DESCRIPTOR
  5  =  LIST ATTRIBUTE FIELDS
  6  =  SEARCH AN ATTRIBUTE FIELD
  7  =  RESEQUENCE INPUT DATA FILE
  8  =  DELETE THE ATTRIBUTE FILE
: 2

WILL YOU BE USING A DEFINITION FILE? [CR = NO]:       YES
ENTER THE NAME OF THE ATTRIBUTE DEFINTION FILE:       COAL.DEF
PLEASE ENTER THE NAME OF THE INPUT DATA FILE:         COAL.DAT

THE NUMBER OF ATTRIBUTES IS    5
THE NUMBER OF ITEMS IS        45

PLEASE ENTER DESIRED OPTION
  1  =  EXIT   [DEFAULT]
  2  =  ADD A NEW ATTRIBUTE
  3  =  UPDATE AN EXISTING ATTRIBUTE
  4  =  CHANGE/DELETE KEY OR DESCRIPTOR
  5  =  LIST ATTRIBUTE FIELDS
  6  =  SEARCH AN ATTRIBUTE FIELD
  7  =  RESEQUENCE INPUT DATA FILE
  8  =  DELETE THE ATTRIBUTE FILE
: 1
**** STOP
MOSS UTILITY SESSION COMPLETED
```

Now the user can use the following commands:

- **DESCRIBE** mapname ATTRIBUTE to view the attribute file.
- **SELECT**, **WINDOW** and **PLOT** the drillhole-location map.
- **LEGEND** mapid LABEL to plot the subject or an attribute next to the drill-hole locations.
- **SELECT** mapname ATTRIBUTE to select a specific attribute for plotting on the screen.
- **REPORT** to create a table that lists the attributes as specified by the user.
- **QUERY ATTRIBUTE** to query a specific point on the plotted drillhole-location map.
- **BSEARCH** to perform complex Boolean retrievals of information from the attribute file of a map.

If necessary, attributes can be edited with the **UTILITY-ATTRIBUTES** command (Option 3-update an existing attribute) or the **EDITATT** command. The first command will use a data file to modify all the values for an existing attribute; the second command uses the crosshairs to locate a specific drill hole and modify, by key entry, a specific attribute, or all the attributes, for that drill hole.

SECTION FIVE: CREATE A BORDER MAP FOR THE STUDY AREA

Before generating isopach and structure maps, a border map must be created that will be used as the "window" for all **MAPS** analyses. The border map is essential in the analyses as all the cell maps must have the same number of cells (rows and columns) and the same cell size.

There are several ways to do this depending on what maps are available.

If there is a specific lease/tract boundary for the study area:

- **SELECT**, **WINDOW** and **PLOT** the landlines (township, range) map(s).
- **WINDOW** the active ID(s) of the landline map(s).
- **SELECT** and **PLOT** the lease boundary that is within the landline boundary.
- Use the **GENERATE** command and the crosshairs to create a rectangle just oustide the lease boundary. Name the new map BORDER.
- **SELECT** and **WINDOW** the BORDER map. Use this window for all **MAPS** analyses for a project.

If there is no specific lease or other boundary, use the drillhole-location map to create a BORDER map:

- **SELECT**, **WINDOW** and **PLOT** the location map.
- Use the command **ZOOM POINT** with a factor of .9 or .8.
- **ERASE** the screen and rePLOT the location map.
- Use the **GENERATE** command to create a rectangle by positioning the crosshairs just inside the corners of the enlarged map. Name

the new map BORDER.
SELECT and **WINDOW** the BORDER map. Use this window for all the **MAPS** analyses for the project.

SECTION SIX: USE TESTGRID TO DETERMINE THE CELL SIZE FOR THE GRID

Prior to the gridding process, the user must determine an appropriate grid cell size. The **TESTGRID** command can be used to visually determine what cell size would be most useful.

PLOT the drillhole-location map
Use the **TESTGRID** command
A general "rule"-- no more than 1 point to a cell; points not more than 10 cells away from each other.

SECTION SEVEN: THE ABC'S OF GRIDDING

The **MOSS GRID** command converts a point-value map (e.g., observed thickness of coal) into a uniform set of rows and columns, thus defining a grid made up of "cells". Each cell is assigned a specific value that has been interpolated by **MOSS** from the observed point-values. The grid can then be used to generate a contour map (e.g., isopach map) or in further analyses (.e.g., adding grids of several coal beds to obtain a grid of total coal thickness).

GRIDDING ALGORITHMS IN MOSS:

There are 5 gridding algorithms available in **MOSS**. Each one treats the gridding process differently, and the user should select an algorithm depending on the configuration of the data (e.g., clustered, widely scattered, etc.) and his/her geostatistical knowledge. The gridding algorithms available in **MOSS** are as follows:

4-POINT/QUADRANT WEIGHTED AVERAGE: Searches in four directions (quadrant) from a target cell to find the four nearest observed values and then calculates the weighted average of those values for the cell. The value (z) for a cell is determined by this equation:

$$z = \frac{z_1/d_1 + z_2/d_2 + z_3/d_3 + z_4/d_4}{1/d_1 + 1/d_2 + 1/d_3 + 1/d_4}$$

where:
z = the cell value to be determined
1...4 = the value of the observed points
d = the distance from an observed point to the center of the target cell

This algorithm works better than others when there is a clustering of the data.

8-POINTS WEIGHTED AVERAGE: Searches in all directions for the 8 nearest observed point-values from the target cell. The z value of the cell is then calculated by a similar formula as above except for 8 points rather than 4. The **8-POINT** algorithm produces a smoother contour map than the 4-**POINT**.

KRIGING: Estimates the value of a spatially distributed variable from adjacent values while considering their interindependence as shown in a variogram. The user should not attempt to run the KRIGING option without some understanding of the theory of geostatistics.

QUINTIC SPLINE INTERPOLATION: Divides the area into triangles using the points as vertices of the triangles. It then defines a 5th degree (quintic) polynomial over each triangle in such a manner that the polynomials of adjacent triangles match smoothly (spline). This gridding algorithm is good for interpolating within the convex hull of the data points; not good for outside this hull.

> NOTE: The **QUINTIC SPLINE** method cannot be used if two points have the same geographic coordinates. The **VARIOGRAM** command can be used to identify such points as it lists the item numbers of the duplicate points. The **SELECT** command can then be used to not-select the duplicate item numbers.

NEAREST NEIGHBOR (POLYGON): Searches for the value of the closest data point to the target cell and assigns this value to the cell. If more than one data point is available to the target cell, it is assigned the average of the data points. The resulting cell map appears to made of polygons.

Several of the above gridding algorithms will ask for the size of a "roving window" (a moving matrix of cells). The user-specified window size defines the number of cells (in both x- and y-dimensions) that the gridding algorithm will search for the required number of observed point-values. If three points cannot be found within the window, the target cell is given the value of zero.

SECTION EIGHT: CREATE AN ISOPACH-GRID MAP

STEP 1. **SELECT** the drillhole-location map by the thickness attribute or **BESEARCH** the map using the Boolean operators, such as in the following example:

```
        BSEARCH COAL.PTS
              THICKNESS GT 0
```

STEP 2. Use the **GRID** command:

```
WINDOW the BORDER map    [as created in SECTION FIVE]
GRID the thickness map  [using cell size determined in
                                      SECTION SIX]
```

An example of the **QUINTIC SPLINE** gridding method is as follows:

```
GRID the active table ID # for thickness values
   MENU #?                5 [Quintic Spline]
   MASKING MAP?          NO
   SCALER:                1
   ACRES OR METERS?       M
   CELL WIDTH?          500
   CELL HEIGHT?         500
   REENTER PARAMETERS?  N
   NO. OF CLOSEST DATA POINT TO USE?   7
   IS THIS A RESTART?   N
```

The user should create and plot various types of grids and choose the best one for the data in the study area. The **QUINTIC SPLINE** algorithm creates the grid faster but needs a wide-spread control by the data or it will see trends where the data are absent. For clustered data, use the **4-POINT/QUADRANT WEIGHTED** algorithm.

The grid may then be **SELECT**ed and **PLOT**ted on the screen. The drillhole-location map and other available maps (e.g., lease boundary) can be **PLOT**ted over the isopach-grid map. See FIGURE 6 (A through C) for examples of the **4-POINT**, **8-POINT** and **QUINTIC SPLINE** grids using the same data set.

SECTION NINE: CREATE A STRUCTURE-GRID MAP

The process is the same as the isopach map except that the attribute for the elevation for the top of the coal bed is used instead of the coal thickness. See FIGURE 7 for an example of a structure map generated by the **QUINTIC SPLINE** method.

Other **MOSS** commands that can be used with the grid map:

- The **SCAN** command in **MAPS** can be used on the grid-map to eliminate excessive contour islands in the plot.
- The **CONTOUR** command in **MOSS** will create a line map from the grid map. The **SMOOTH** command in **MOSS** will make the contour line map smoother each successive time it is used.
- The contour lines can be labeled using the **LEGEND - CONTOUR** command or the **AUTOLABEL** command.
- Other maps can be **PLOT**ted over the contour map, such as the drillhole-location map, lease map, landlines, roads, streams, etc.

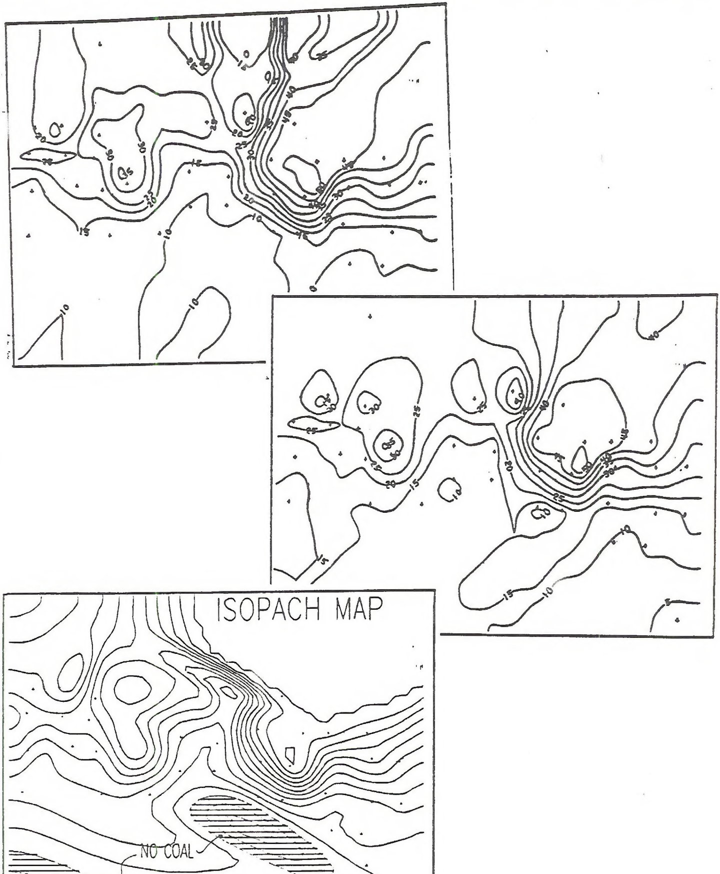


FIGURE 6. Isopach map generated by the following gridding algorithms: (A) 4-POINT QUADRANT; (B) 8-POINT WEIGHTED; AND (C) QUINTIC SPLINE.

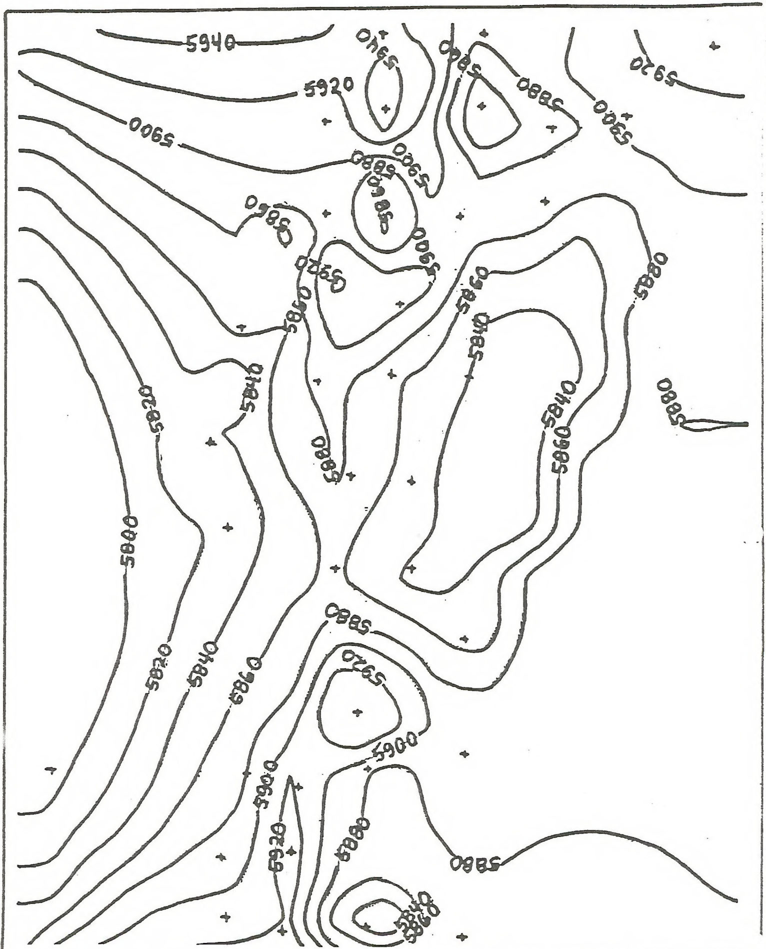


FIGURE 7. Structure map generated by the QUINTIC SPLINE gridding

- For a hardcopy map, the maps can be plotted to a specified scale using the **PENPLOT** command.

NOTE: The **SCAN** and **SMOOTH** commands will often smooth out contours so that they no longer honor the data points, i.e., the 10' contour may not go through a 10' data point. Remember, however, that it is the grid (not the contour line map) used in **MAPS** analyses, such as calculating coal tonnage.

SECTION TEN: EDITING THE GRID, IF NECESSARY

Once the grid is generated, the geologist/engineer can determine if it geologically acceptable. If not, either try other parameters (cell size, window) or another gridding algorithm...or edit the grid.

Editing may consist of one or more of the following methods:

1. Use the **DESCRIBE** command to see if the grid has cell values that are negative or are higher than the the largest observed data value. This would be especially true if the **QUINTIC SPLINE** algorithm was used as it creates trends where observed data is sparse or lacking. The **RENUMBER** command can be used to change these values in the grid. Here is an example:

```
MAPS
DESCRIBE THICK.GRD HEADER
WINDOW BORDER
RENUMBER THICK.GRD FOR NEWTHK.GRD ASSIGN 0 TO -50 TH 0 ,
   ASSIGN 25 TO 25 TH 50
```

2. Data errors can sometimes be spotted when plotting the grid and there are isolated areas with tight concentric contours. These data errors can also be seen as spikes (positive or negative) in a three-dimensional display of the grid using the **3D** command in **MAPS**. The data errors can be deleted by one of 2 methods:

   a. **PLOT** and **QUERY** the map to determine the item numbers of the drill holes that have data errors. Then **SELECT** the drillhole-location map by ITEM and use the non-select option (a backslash).

   ```
   SELECT mapname ITEM
     \45 57                    [not items 45 and 57]
   ```

   This selection can then be saved for a new map using the **SAVE** command. The gridding process must then be redone using the new map.

   b. Use the **EDMAP** command to delete the points using the crosshairs and create a newmap. Again the gridding must be redone using the new map.

3. Use the **EDMAP** command to add control points. Use minimum number of points and re**GRID** before adding more points. Control points work well in the **QUINTIC SPLINE** method, but often just add more circles to the **8-POINT** grid.

4. Change individual or blocks of cell values using the **CUT** command.

5. **CONTOUR** the grid and then use **EDMAP** to change the contour lines. However, this only changes the contour map and not the grid! To get the map back into grid format, use the **CTOG** command and create a grid from the corrected contour map.

When the grid is geologically acceptable to the geologist/engineer, it can be used to generate plots (isopach maps, structure maps) or in further data analyses such as:

```
MATH DEMgrid - structure.grid FOR overburden.grid

MATH isopach1.grid + isopach2.grid FOR total.coal.grid
```

SECTION ELEVEN: COAL RESERVE CALCULATIONS

In calculating coal reserves, the thickness values must first be limited to the lease (or sections within a lease) boundary so that only the coal within that boundary is considered in the calculations. The boundary, which is a vector map, must be rasterized to a create a cell map that has the same cell size and rows and columns as the thickness-grid map. The thickness-grid (feet of coal within the lease boundary) and the rasterized boundary map (acres) are used in the tonnage calculations to obtain acre-feet. A coal factor can also be used. The steps to do this are as follows:

STEP 1. USE THE LPOVER COMMAND TO LIMIT CONTOURS TO LEASE BOUNDARY

SELECT and **WINDOW** the BORDER map.
SELECT the thickness grid and **CONTOUR** it to create a line map (Type 2).
SELECT the contoured map (line map).
SELECT the lease boundary map.
LPOVER the lease and contour maps to create a new map.

STEP 2. CREATE A CELL MAP OF THE LEASE/TRACT MAP

FACTS TO REMEMBER:

Use the BORDER map as the window in all cases so that the resultant cell map has the same number of rows and columns as the thickness grid.

Use the same cell size for all grids and rasterized maps for the the same study area.

If the tonnage is to be calculated by the lease boundary:

Rasterize the boundary map, such as the lease/tract boundary map, using the **MOSS** command **POLYCELL** or the **MAPS** command **RASTERIZE**.

```
SELECT lease.map all.
WINDOW the BORDER map.
POLYCELL the lease.map.
```

If tonnage by section within the lease boundary is required, then the following extra steps must be taken:

```
SELECT the lease.map and the landlines map.
WINDOW the BORDER map.
INTERSECT the landlines map with the lease map.
POLYCELL the intersected map.
```

STEP 3. SET LINES PER PAGE FOR THE REPORT

Before running the **TOTAL** command (for coal tonnage), set the lines per page for printer output to 100 by typing **PAGE** 100. This will change the number of lines per page from 30 to 100 so that a title line does not appear in the middle of the a tonnage report.

STEP 4. USE TOTAL COMMAND TO CALCULATE TONNAGE

Here is an example of using the **TOTAL** command in **MAPS** to calculate coal tonnage.

```
MAPS
WINDOW BORDER
TOTAL THICK.GRD FACTOR 1770 BY LEASE.POL LABEL TONS FOR REPT.LE
```

where THICK.GRD in the thickness grid (or the NEWTHK.GRD if renumbered)
FACTOR is the coal factor, in this case 1770
LEASE.POL is the rasterized lease map
LABEL TONS replaces the default label (PRODUCT) in the report
FOR REPT.LE is the name given the output report file that will list the coal tonnage for the lease

Or if tonnage by section within the lease boundary is required:

```
MAPS
WINDOW BORDER
TOTAL THICK.GRD FACTOR 1770 BY SECTION.POL LABEL TONS FOR REPT.SEC
```

STEP 5. PRINT THE REPORT

The output report will be a text file in your directory. Exit **MAPS** and **MOSS** and print the generated tonnage reports at the **PRIMOS** level. See FIGURE 9 for an example of a coal tonnage report.

NOTE: Tonnage within a specified boundary will not be accurate because the acreage changes when the lease map is rasterized. This error is inherent in working with cell maps. The user can obtain the correct acreage for the lease by using the **AREA** command in **MOSS** and then hand calculate the tonnage by using the average thickness as generated by the **TOTAL** command in **MAPS**.

SECTION TWELVE: USING THE DIGITAL ELEVATION MODEL (DEM) TO CALCULATE THE OVERBURDEN AND LOCATE THE PROBABLE OUTCROP LINE

STEP 1. LOADING THE DEM'S

Call your State GIS Coordinator to obtain both the DEM tape and the position numbers for the 7.5 minute quadrangle(s) required for the study area. (It may be necessary to know the USGS ID for the quadrangles, e.g., B344106.) The system operator will then load the specified tape on the PRIME and inform the user of the drive number.

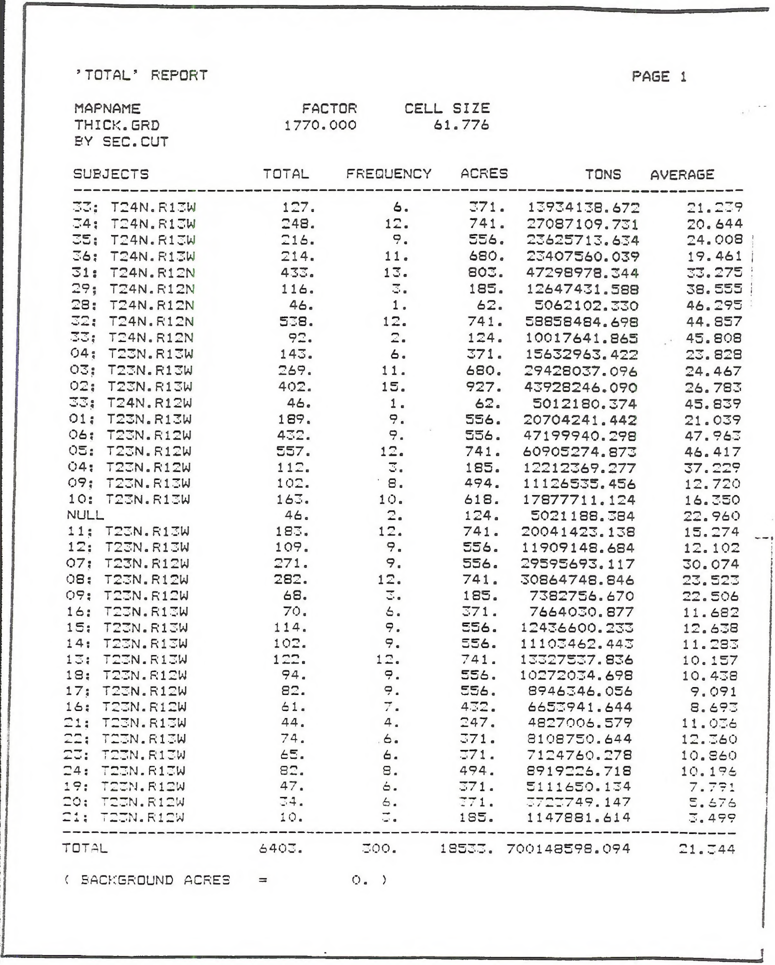
Then type in the following:

```
LOGIN to the PRIME
DOWN directory                     [to user directory]
ASSIGN MT#                        [# = no. of the mount drive on which
MAGNET                                   the tape is loaded]
   READ
   MTU NO .? = #                   [# = no. of mount drive]
   FILE NO.? = #                   [# = file number for the quadrangle]
   LOGICAL RECORD LENGTH? = 1024
   BLOCKING FACTOR? = 4
   TYPE?  ASCII
   DISCFILE? dem.quad             [Enter name to call the output DEM]
```

Repeat for as many quadrangle DEM files needed for the study area.

When a '>' prompt appears, type in QUIT to exit MAGNET.

```
UNASSIGN MT# -UNLOAD       [rewinds tape; # = no. of mount drive]
```



```
'TOTAL' REPORT                                                      PAGE 1

MAPNAME                    FACTOR      CELL SIZE
THICK.GRD                 1770.000        61.776
BY SEC.CUT

SUBJECTS                  TOTAL    FREQUENCY    ACRES          TONS   AVERAGE
-------------------------------------------------------------------------------
33: T24N.R13W              127.           6.      371.   13934138.672     21.239
34: T24N.R13W              248.          12.      741.   27087109.731     20.644
35: T24N.R13W              216.           9.      556.   23625713.634     24.008
36: T24N.R13W              214.          11.      680.   23407560.039     19.461
31: T24N.R12N              433.          13.      803.   47298978.344     33.275
29; T24N.R12N              116.           3.      185.   12647431.588     38.555
28: T24N.R12N               46.           1.       62.    5062102.330     46.295
32; T24N.R12N              538.          12.      741.   58858484.698     44.857
33; T24N.R12N               92.           2.      124.   10017641.865     45.808
04; T23N.R13W              143.           6.      371.   15632963.422     23.828
03; T23N.R13W              269.          11.      680.   29428037.096     24.467
02; T23N.R13W              402.          15.      927.   43928246.090     26.783
33; T24N.R12W               46.           1.       62.    5012180.374     45.839
01; T23N.R13W              189.           9.      556.   20704241.442     21.039
06: T23N.R12W              432.           9.      556.   47199940.298     47.963
05: T23N.R12W              557.          12.      741.   60905274.873     46.417
04: T23N.R12W              112.           3.      185.   12212369.277     37.229
09; T23N.R13W              102.           8.      494.   11126535.456     12.720
10: T23N.R13W              163.          10.      618.   17877711.124     16.350
NULL                        46.           2.      124.    5021188.384     22.960
11; T23N.R13W              183.          12.      741.   20041423.138     15.274
12: T23N.R13W              109.           9.      556.   11909148.684     12.102
07; T23N.R12W              271.           9.      556.   29595693.117     30.074
08: T23N.R12W              282.          12.      741.   30864748.846     23.523
09: T23N.R12W               68.           3.      185.    7382756.670     22.506
16: T23N.R13W               70.           6.      371.    7664030.877     11.682
15: T23N.R13W              114.           9.      556.   12436600.233     12.638
14: T23N.R13W              102.           9.      556.   11103462.443     11.283
13: T23N.R13W              122.          12.      741.   13327537.836     10.157
18: T23N.R12W               94.           9.      556.   10272034.698     10.438
17; T23N.R12W               82.           9.      556.    8946346.056      9.091
16; T23N.R12W               61.           7.      432.    6653941.644      8.693
21; T23N.R13W               44.           4.      247.    4827006.579     11.036
22; T23N.R13W               74.           6.      371.    8108750.644     12.360
23: T23N.R13W               65.           6.      371.    7124760.278     10.860
24: T23N.R13W               82.           8.      494.    8919226.718     10.196
19: T23N.R12W               47.           6.      371.    5111650.134      7.791
20: T23N.R12W               34.           6.      371.    3722749.147      5.676
21; T23N.R12W               10.           3.      185.    1147881.614      3.499
-------------------------------------------------------------------------------
TOTAL                     6403.         300.    18533. 700148598.094     21.344

( BACKGROUND ACRES    =           0. )
```

FIGURE 9. Listing of coal tonnage within each section of a lease

STEP 2. CONVERTING THE DEM

This section will take the user through the necessary steps to prepare a DEM (Digital Elevation Model) so that it has the same projection, cell size, map size (rows and columns), and unit of measurement (feet rather than meters) as the thickness and structure grids so that it can be used in **MAPS** analyses. For example, the structure grid can be subtracted (using **MATH** command) from the DEM to obtain the overburden grid.

A. Log into **MOSS** and then into **MAPS**.

B. **IMPORT** the DEM file:

```
IMPORT dem.quad FORMAT DEM 7.5 TYPE 8 for dem.map
```

where dem.quad is the output DEM file from Step One and dem.map is name for the output map generated by the **IMPORT** command.

C. **MERGE** the DEM files if more than one was needed for the study area:

```
MERGE dem.map1 with dem.map2 for demproject
```

D. Re**PROJECT** the DEM file into projection used with other maps in the study area:

```
PROJECT demproject FOR dem.rep
```

E. To convert to the cell size of the DEM to the cell size of the thickness and structure grids, use the **RESAMPLE** command:

```
RESAMPLE dem.rep FOR dem.resam SIZE #
```

where # is the cell size

F. **DESCRIBE** the resampled DEM and the thickness or structure grid to see if the number of rows and columns are the same in each map. Most likely the DEM will be a larger map and the **CUT** command must be used to reduce the DEM grid to the same size as the thickness and structure grids in order to do any analyses:

```
MAPS
WINDOW the BORDER map.
CUT dem.resam WINDOW FOR dem.cut
```

G. To convert elevations from meters to feet in the DEM file:

```
MATH dem.cut * 3.280839894 FOR dem.ft
```

STEP 3. COMPARE THE DEM MAP TO DRILL-HOLE COLLAR ELEVATIONS

The collar elevation at the drill-hole location should be checked against the surface elevation as given by the DEM at that location. If there is a substantial discrepancy between the collar elevation and the surface elevation of the DEM, these differences will have to be evaluated by the geologist/engineer and corrections made, if necessary, to the structure and thickness values. The procedure to do this is as follows:

Enter **MAPS**.
WINDOW the BORDER map.
RASTERIZE the drillhole-location map by the collar elevation attribute for a TYPE 7 map using the same cell height and width as used with the thickness grid:

```
RASTERIZE DH.MAP BY ATTRIBUTE # FOR COLLAR.RAS ,
  HEIGHT 500 WIDTH 500
```

where,
DH.MAP is the drillhole-location mapname
# is the id number of the collar elevation attribute
COLLAR.RAS is the name given the output map
500 is the same cell size in the thickness grid

Subtract the rasterized map from the DEM:

```
MATH DEM.FT - COLLAR.RAS for DIFF
```

TOTAL the resulting map by the rasterized map:

```
TOTAL DIFF BY COLLAR.RAS FOR REPT.DIFF
```

The report will be generated in the user's directory. The report can then be listed on the screen or printed to hard copy. The column in the report that lists the total is the difference between the DEM elevation at a specific point and the collar elevation.

SECTION THIRTEEN: GENERATE AN OVERBURDEN MAP

SUBTRACT the structure grid from the DEM

Remember, the DEM must have elevation coverted to feet, cell size the same as the structure grid and cut to the same window.

See FIGURE 10 for an example of a generated overburden map.

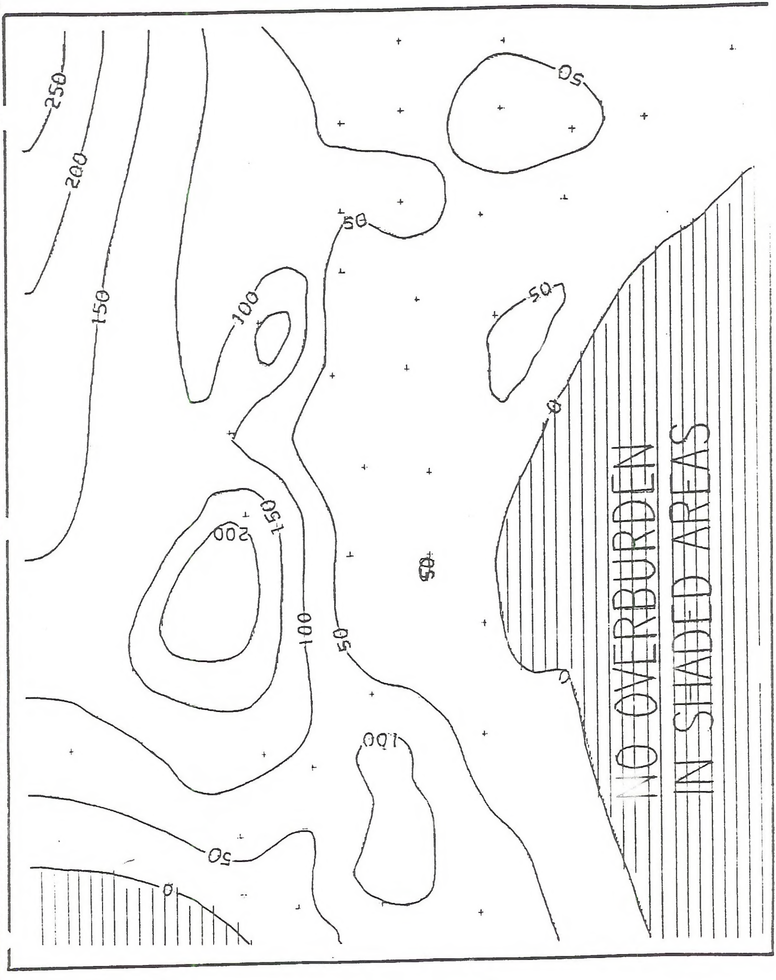


FIGURE 10. Overburden map generated by the QUINTIC SPLINE gridding

SECTION FOURTEEN: GENERATE A MINE-STRIPPING RATIO MAP

A mine-stripping ratio map can be generated to limit the extent of the overburden, interburden or coal:

POLYCELL the bed limit polygon
RENUMBER the polygon area to 1
RENUMBER the rest of the map to 0

Using the **MATH** command add the overburden and interburden grids together and add the coal bed grids together as follows:

MATH (overburden + interburden) / ($coal_1$ + $coal_2$ + $coal_n$) ,
* factor FOR strip.map

The factor is determined by the user. An example of the factor is:

$$\frac{\text{1613.33 cubic yds. / acre-foot}}{\text{(1742 tons/acre-foot) * .90 recovery factor}} = 1.03$$

NOTE: If overburden includes coal beds, then use **MATH** to subtract these beds from the total overburden:

MATH (overburden - sum coal thickness + interburden) / ,
sum of coal thickness * factor FOR strip.map

See <u>FIGURE 11</u> for an example of a generated mine-stripping ratio map.

SECTION FIFTEEN: CREATING ISOPLETH MAPS

Isopleth maps can be generated by **SELECT**ing the point map by a chemical attribute, such as ash, sulfur, BTU/LB, etc. For example:

```
SELECT  mapname ATTRIBUTE
     KEY?    ASH
     2 = BOUNDED SEARCH
     LOWER BOUND = .01
     UPPER BOUND = 100
GRID the attribute ash
PLOT the grid
```

Repeat this procedure for each attribute required. These grids can be **CONTOUR**ed and **SMOOTH**ed.

SECTION SIXTEEN: PREPARING THE FINAL MAPS

For screen display:

The **TEXT** command creates a text file that can be plotted over the maps already **PLOT**ted onto the screen. The **AUTOLABEL** command

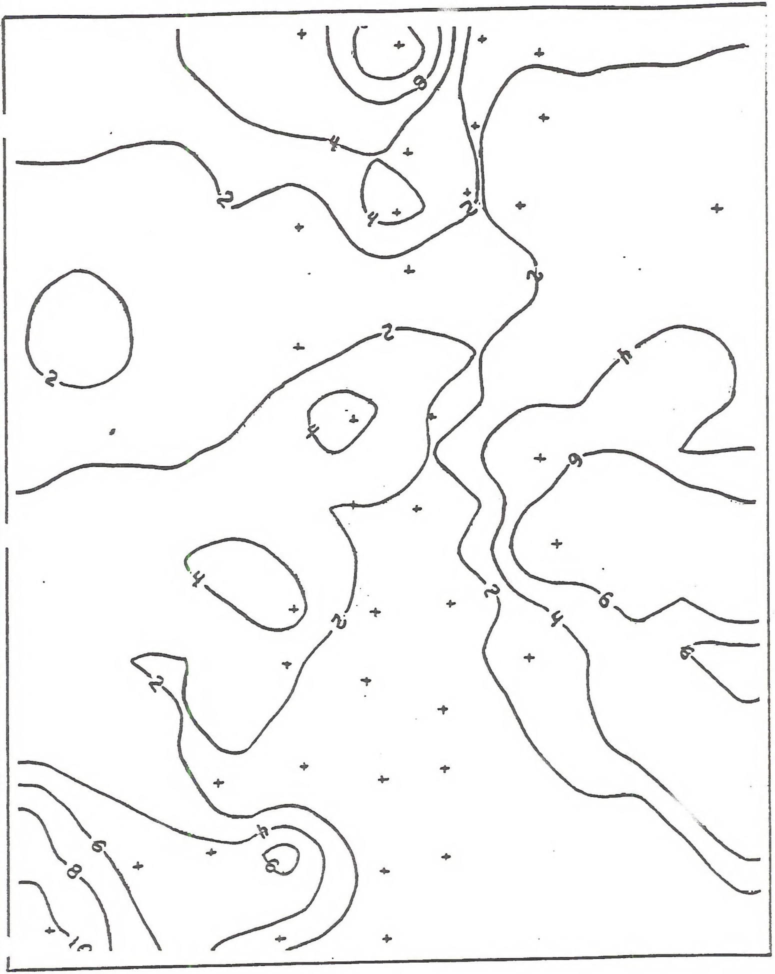


FIGURE 11. Mine-stripping ratio map generated by the QUINTIC SPLINE

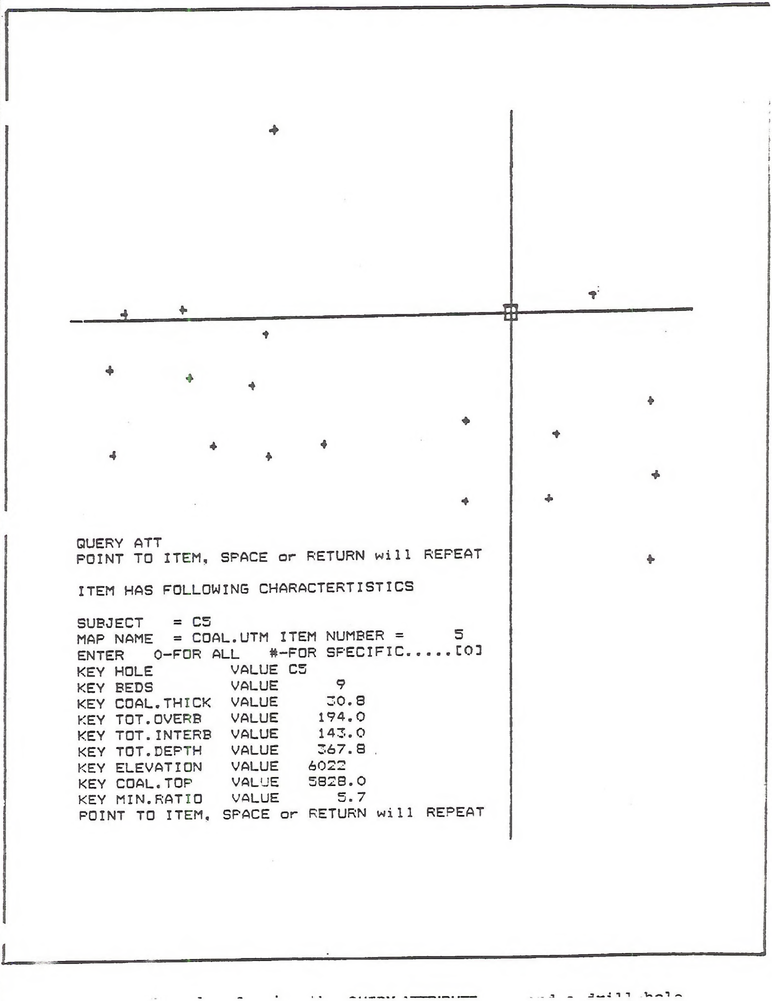
inserts labels (values) in the contour lines of the contour map (line map, not the grid).

For the CALCOMP or similar plotter:

The **PENPLOT** command produces a plot file of a map at a user-specified map scale. This file can then be used to produce a paper or mylar map on a plotter.

SECTION SEVENTEEN: EXAMPLES OF ANALYSES

FIGURES 12 through 14 show various ways the generated maps can be used in **MOSS** and **MAPS** to analyze data:



```
QUERY ATT
POINT TO ITEM, SPACE or RETURN will REPEAT

ITEM HAS FOLLOWING CHARACTERTISTICS

SUBJECT    = C5
MAP NAME   = COAL.UTM ITEM NUMBER =       5
ENTER   0-FOR ALL   #-FOR SPECIFIC.....[0]
KEY HOLE         VALUE C5
KEY BEDS         VALUE       9
KEY COAL.THICK   VALUE      30.8
KEY TOT.OVERB    VALUE     194.0
KEY TOT.INTERB   VALUE     143.0
KEY TOT.DEPTH    VALUE     367.8
KEY ELEVATION    VALUE   6022
KEY COAL.TOP     VALUE   5828.0
KEY MIN.RATIO    VALUE       5.7
POINT TO ITEM, SPACE or RETURN will REPEAT
```

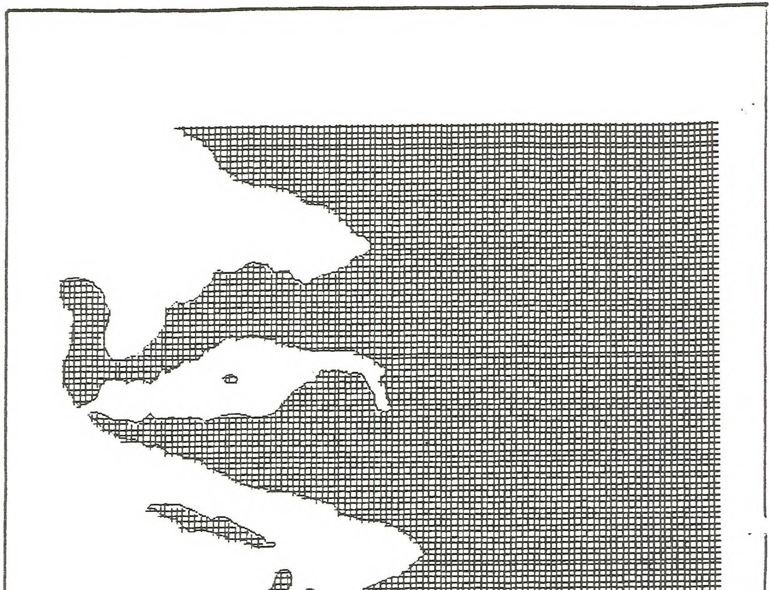


FIGURE 13. Outcrop map generated using the DEM (Digital Elevation Model) for the surface grid and substracting the structure grid to find where the overburden equals zero.

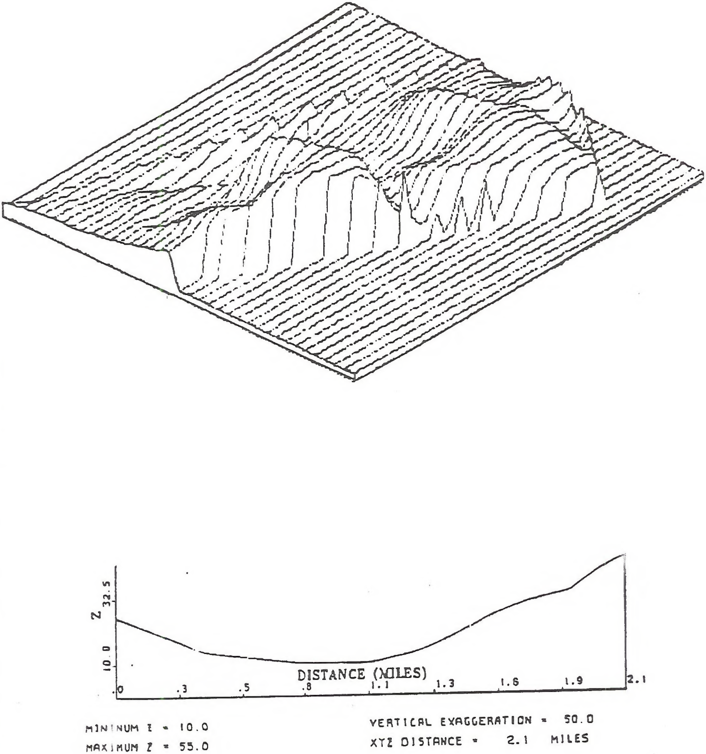


FIGURE 14. (A) Example of the 3D command showing coal thickness in a
model (B) Example of the PROFILE command

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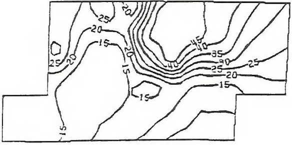
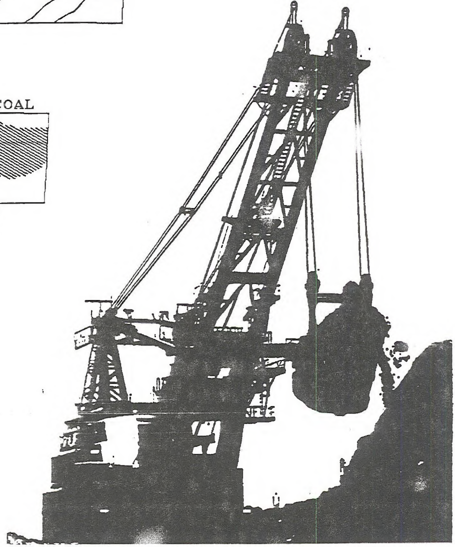
GIS APPLICATIONS FOR SOLID MINERALS


ISOPACH MAP

SURFACE MINABLE COAL



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